Part 4
Highway Traffic Signals

Prepared by:

Traffic Engineering and Safety Systems Branch
Division of Highways
North Carolina Department of Transportation (NCDOT)

Last update: November 2004

PART 4. HIGHWAY TRAFFIC SIGNALS

TABLE OF CONTENTS

CHAPTER 4K. FLASHING BEACONS

CHAPTER 4A. GENERAL

Section 4A.02 Definitions Relating to Highway Traffic Signals

Standard:

The following terms are intended to supplement the definitions as defined in Part 4 of the *MUTCD*. When used in the *NCSMUTCD*, they shall be defined as follows:

1. **Combination Lane – A lane designated to allow two or more separate movements from the same lane. These movements may include through-left, through-right, right-left, or left-through-right. For lane assignment and traffic control purposes, U-turns are considered to be left-turns.**

2. **Exclusive Turn Lane – A turn lane, either left or right, serving only one movement. This lane may be controlled either independently (protected movement) or in conjunction with (permitted movement) the adjacent through movement. If multiple left-turn lanes exist, U-turns, if permitted, shall be made only from the inner-most left-turn lane (closest to the median).**

3. **Overlap – The additional assignment of right-of-way for a traffic movement associated with one or more phases other than its normal phase.**

4. **Pedestrian Phase – See Phase.**

5. **Phase – The right-of-way assignment of one or more traffic or pedestrian movements within the signal cycle.**

    a. **Pedestrian Phase – Those right-of-way and clearance intervals assigned to a phase within the signal cycle for pedestrian movement either concurrently with one or more vehicular movements, or to the exclusion of all vehicular movement.**

    b. **Traffic Phase – Those right-of-way and clearance intervals assigned to a phase within the signal cycle for vehicular movements.**

6. **Split Phase – A type of signal phasing where opposite approaches at an intersection are each given their own right of way phase independent and free of conflict from all other movements at the intersection.**

7. **Strobe Light – A supplementary electronic flashing device providing a high-intensity pulsating light usually placed in the red section of a traffic signal head to alert drivers of the red display.**

8. **Traffic Phase – See Phase.**

CHAPTER 4D. TRAFFIC CONTROL SIGNAL FEATURES

Section 4D.04 Meaning of Vehicular Signal Indications

Standard:

Vehicular traffic facing a steady CIRCULAR RED or RED ARROW signal indication shall stop at a clearly marked stop line; but if there is no stop line, traffic shall stop before entering the crosswalk on the near side of the intersection; but if there is no crosswalk, then before entering the intersection, and shall remain stopped until a signal indication to proceed is given, or as provided below.

Except when a sign is in place prohibiting a turn on red, vehicular traffic facing a steady CIRCULAR RED or RED ARROW signal indication may enter the intersection to turn right after stopping. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.

Where turning movements are not allowed when a traffic signal is emitting a steady red indication, a "NO TURN ON RED" sign (R-10-11 or R10-11b) shall be used.

Support:

General Statute 20-158(b)(2) of the Motor Vehicle Laws of North Carolina states "except where prohibited by an appropriate sign, vehicular traffic facing a red light controlling traffic passing (straight) through an intersection, after coming to a complete stop at the intersection, may enter the intersection to make a right turn but such vehicle shall yield the right of way to pedestrians and to other traffic using the intersection."

Although not specifically defined by the general statutes, a red light is implied to be either a **CIRCULAR RED** or a **RED ARROW**.

To reduce potential motorist confusion and misinterpretation of the meaning of signal indications, the use of consistent signage prohibiting or allowing turns on red indications is encouraged. Motorists usually assume they can turn unless a sign is in place prohibiting the movement.

Section 4D.05 Application of Steady Signal Indications

Standard:

Steady signal indications shall be applied as follows:

A. A steady RED ARROW signal indication:

1. A steady RED ARROW signal indication shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal

head, from entering the intersection or other controlled area to make the indicated turn. Turning after stopping is permitted as stated in Section 4D.04 of this supplement.

2. Where turning movements are not allowed when a traffic signal is emitting a steady CIRCULAR RED or RED ARROW indication, a "NO TURN ON RED" sign (R-10-11 or R10-11b) shall be used in conjunction with the steady red signal indication.

B. A steady GREEN ARROW signal indication:

When the protected left-turn movement of a GREEN ARROW is accompanied by a simultaneous overlap display of a right-turn GREEN ARROW and a median exists adjacent to the left-turn lane(s), a "U-TURN YIELD TO RIGHT TURN" sign (R10-16) shall be used and mounted adjacent to the left-turn signal head. If more than one left-turn signal head exists, then the "U-TURN YIELD TO RIGHT TURN" sign (R10-16) shall be mounted adjacent to the signal head closest to the median (serving the inner-most turn lane).

Support:

At some intersections with a physical median (barrier wall, monolithic island, grass island, etc.), the potential exists for some traffic in the left-turn lane to make a U-turn movement. When this U-turning traffic moves on a left-turn **GREEN ARROW**, a conflict could be encountered if the adjoining street has a right-turn **GREEN ARROW,** which displays as an overlap simultaneously with the left-turn movement. In case of such conflict, the right-turn movement has right of way over the U-turn movement.

Guidance:

When the protected left-turn movement of a GREEN ARROW is accompanied by a simultaneous overlap display of a right-turn GREEN ARROW and there is a high potential for a U-turn movement, a "U-TURN YIELD TO RIGHT TURN" sign (R10-16) should be used and mounted adjacent to the left-turn signal head, even if the median is a double yellow line or part of a two-way left-turn lane.

Option:

An existing "U-TURN MUST YIELD" sign (R3-27) may be used in place of the "U-TURN YIELD TO RIGHT TURN" sign (R10-16) for the remainder of its useful service life.

Section 4D.06 Application of Steady Signal Indications for Left Turns

Standard:

A 3 section left RED, YELLOW, and GREEN ARROW indication shall be the standard display for all protected only (exclusive) mode left-turn movements. No sign is

required in conjunction with the use of this type of signal head; however, if one is used, it shall be a "LEFT ON GREEN ARROW ONLY" sign (R10-5).

At least one 3 section head consisting of left RED, YELLOW, and GREEN ARROW indications shall be used for single lane protected only left-turn approaches. At least two 3 section heads consisting of a left RED ARROW, YELLOW ARROW, and GREEN ARROW indication shall be used for multi-lane left- turning movements.

If a 4 section T-head signal head or 4 section vertical head consisting of two CIRCULAR RED and separate left YELLOW ARROW and GREEN ARROW indications is used, in accordance with the option below, a "LEFT TURN SIGNAL" sign (R10-10L) shall be used adjacent to the signal head.

Guidance:

At signalized locations, a protected only (exclusive) left-turn movement should be provided when there are two or more left-turn lanes on the same approach at an intersection subject to conflicts from opposing through traffic. If one of the left-turn lanes is a shared movement lane, then the use of split phasing should be considered.

Option:

For a single left-turn lane approach operating as a protected only left-turn, a 4 section T-head signal head or 4 section vertical head consisting of two **CIRCULAR RED** and separate left **YELLOW ARROW** and **GREEN ARROW** indications, in conjunction with an adjacent "LEFT TURN SIGNAL" sign (R10-10L) when the **CIRCULAR RED** indications are readily visible to other traffic, may be used. An existing 4-section signal head may be used for the remainder of its useful service life.

Section 4D.10 Yellow Change and Red Clearance Intervals

Standard:

The yellow change interval shall be followed by a red clearance interval before conflicting traffic movements are given the right-of-way.

The use of red light camera photo enforcement systems shall not be a consideration in determining the duration of yellow and red clearance intervals.

Guidance:

The red clearance interval should be between 1.0 and 6.0 seconds in duration.

Option:

The red clearance interval may be omitted if the designated phase is an all red clearance holding (dummy) phase.

Longer clearance intervals may be used on approaches with higher speeds or severe downhill grades or other high judgement areas.

Section 4D.11 Application of Flashing Signal Indications

Support**:**

Section 4D.12 of the *MUTCD* requires that "during programmed changes, no steady green signal indication or flashing yellow signal indication shall be terminated and immediately followed by a steady red or flashing red signal indication without first displaying the steady yellow signal indication." This implies that left-turn **ARROWs** flash red in order to properly clear from the flashing mode. If the **YELLOW ARROW** flashed concurrently with the adjoining **CIRCULAR YELLOW** of the through phase, and the opposing through movement also flashed a **CIRCULAR YELLOW**, then a display conflict, as defined in Section 4D.09 of the *MUTCD*, is created when the signal changes from flashing mode to steady mode. This display conflict is created when a steady left-turn **YELLOW ARROW** is displayed simultaneously with a **CIRCULAR YELLOW** on the opposing through movement. Since a flashing yellow indication must clear to either a steady green or steady yellow when changing from flashing mode to steady mode, there is no way that this conflict can be prevented.

There is no clearance conflict created by a flashing right-turn **YELLOW ARROW**. Vehicles turning right on a flashing yellow typically yield only to pedestrians crossing the intersection. During flashing operation, pedestrian signal heads are usually dark. During steady (stop and go) operation, pedestrian signal heads typically display a steady **DON'T WALK** during the yellow clearance interval of the accompanying through movement. The transition from a flashing **YELLOW ARROW** to a steady **YELLOW ARROW** during a change from flashing operation to steady operation does not create a signal head display or vehicular movement conflict.

Driver expectancy also supports that a vehicle is normally required to stop when it approaches a three section **ARROW** signal head. Under normal circumstances, as a driver approaches the intersection, a **RED ARROW** indication is displayed on the signal head. Once a phase call is received through the vehicle detectors, the signal will cycle and display a **GREEN ARROW** for the turning movement to proceed through the intersection without conflict.

Standard:

All signal head indications for the same approach shall flash concurrently during flashing operation.

A RED ARROW indication shall be flashed when a left-turn signal face consists entirely of ARROW indications and is used exclusively in the protected mode under normal operating conditions. Where a 4 section "Tee-Head" or 4 section vertical signal head is used for protected left-turn control under normal operating conditions, both RED CIRCULAR indications shall be flashed. These RED CIRCULAR indications shall flash simultaneously with each other.

Option:

A **YELLOW ARROW** indication may be flashed when a right-turn signal face consisting entirely of a 3 section signal head with either a **CIRCULAR RED** or **RED ARROW** indication and **YELLOW ARROW** and **GREEN ARROW** indications are used exclusively for right turn control under normal operating conditions. This **ARROW** indication normally flashes concurrently with the flashing **CIRCULAR YELLOW** indication of the adjacent through movement on the main street.

A **YELLOW ARROW** indication may be flashed when a signal face consists entirely of arrow lenses and is used for split phase control on the main street under normal operating conditions. This **ARROW** indication normally flashes concurrently with the flashing **CIRCULAR YELLOW** indication of the adjacent movements on the main street approach.

Section 4D.12 Flashing Operation of Traffic Control Signals

Support:

As a means of reducing delays at signalized intersections, some traffic control signals are programmed to operate in a flashing mode during off-peak hours. The off-peak period generally consists of the hours between Midnight (12:00 AM) and 5:00 AM, but is defined differently for individual traffic control signals based on the operational needs at that particular location.

Standard:

Traffic signals with railroad preemption shall not be programmed to operate in a flashing mode during off-peak hours.

If a traffic control signal is programmed to operate in a flashing mode, programmed changes from steady (stop-and-go) mode to flashing mode shall be made at the end of the common major roadway red interval (such as just prior to the start of the green in both directions on the major roadway).

Guidance:

If a traffic control signal is programmed to operate in a flashing mode during off peak hours, the agency responsible for the operation of the traffic control signal should establish a periodic review program to verify that the flashing operation has not had a detrimental effect on safe travel through the intersection. At a minimum, the review program should consist of periodically reviewing data for crashes that occur during the hours of programmed flashing mode.

The decision to operate a traffic signal in either a steady (stop-and-go) mode or in a flashing mode during off-peak hours should be based on sound engineering analysis and the intrinsic operational characteristics specific to the location.

Option:

Traffic signals with preemption, excluding railroad preemption, may be considered for off peak flashing operation if it is determined that the operation of the vehicle benefiting from preemption is not otherwise significantly impacted and safe travel through the intersection is not jeopardized.

The following considerations are among those that may be used for selecting the mode of operation:

- Sight distance
- Night-time volume ratio
- Operation of adjacent signals
- Pedestrians
- Original intent of signal
- Crash history of adjacent signals
- Type of signal
- Adjacent land uses
- Days and times signal will flash

Section 4D.14 Coordination of Traffic Control Signals

Guidance:

Traffic signals operating within 1 mile (1600 meters) of each other should be considered for coordination. Additionally, signals located such that the travel time between them is less than or equal to one cycle length should be considered for coordination.

Traffic signals operating along a main highway corridor, on a corridor that has unpredictable heavy traffic flow, or on a road considered key to a regional network should be considered for interconnected coordination.

Support:

Coordination provides system control of the cycle length if necessary for events that include, but are not limited to, evacuation of coastal and low lying, flood prone areas, and establishing detour routes when a major superhighway, such as an interstate, is closed or experiences a significant incident. During major events, coordination can assist in the progressive flow of heavy traffic along major arterial routes, which might otherwise operate efficiently during normal traffic conditions.

Section 4D.15 Size, Number, and Location of Signal Faces by Approach

Support:

The NCDOT Traffic Engineering and Safety Systems Branch generally acknowledges the posted speed limit as the accepted design speed for traffic control purposes. In some cases, traffic flows at a speed different than the posted speed limit. For this reason, some traffic control devices are designed for operating speeds different than the posted speed limit.

Standard:

Twelve (12) inch (300mm) signal lenses shall be used:

- **On approaches where the design speed exceeds 35 MPH (56 km/hr);**
- **When the nearest signal face is between 120 feet (35 meters) and 150 feet (45 meters) beyond the stop line, unless a supplemental near side signal face is provided;**
- **When signal faces are located more than 150 feet (45 meters) from the stop line;**
- **For approaches to all signalized intersections for which the minimum visibility distance in Table 4.1 of the *MUTCD* cannot be met;**
- **For all ARROW sections;**
- **At intersections with ramp terminals where traffic exits a superhighway (freeway).**

Guidance:

Twelve (12) inch (300 mm) signal lenses should be used in all traffic signal heads.

Option:

Eight (8) inch (200 mm) signal lenses may be used in traffic signal heads.

- On approaches where the design speed is 35 MPH (56 km/hr) or less.
- An engineering study indicates that extra visibility or target value does not provide a significant benefit.

Section 4D.17 Visibility, Shielding, and Positioning of Signal Faces

Support**:**

At some intersection approaches, it is desirable to provide even greater visibility requirements than the measures discussed in the *MUTCD*. In addition to tunnel visors, optically programmable lenses, louvers, backplates, and tethering are acceptable methods of increasing visibility. Tethering allows for the signal head to be attached to span wire on both the top and bottom of the housing to reduce swaying due to wind.

Standard:

The bottom of a signal face mounted or suspended over a roadway shall be at least 16.5 feet (5.0 meters) above the crown of pavement.

Optically programmed heads shall not be mounted in a free-swinging manner.

Option:

Rigid mast arm mountings are preferable for optically programmed heads; however, span wire mountings may be used provided that the bottom of the signal head is tethered.

Section 4D.18 Design, Illumination, and Color of Signal Sections

Guidance:

The exterior housing of all traffic signal sections and visors should be highway yellow in color to obtain the best possible contrast with the visual background.

Option:

The exterior housing of all traffic signal sections and visors may be dark green or black in color if any of the following conditions are met:

- The traffic signal installation is at a low speed (less than 40 MPH) location.
- The traffic signal installation is in a historic district or central business district.
- The local municipality is responsible for maintaining the traffic signal installation.

CHAPTER 4F. TRAFFIC CONTROL SIGNALS FOR EMERGENCY-VEHICLE ACCESS

Section 4F.01 Applications of Emergency-Vehicle Traffic Control Signals

Guidance:

Vehicles eligible to be considered for special right of way preemption should include official first response emergency vehicles that utilize sirens and flashing red lights to provide services to the public which prevent loss of life and/or property. When the emergency vehicle building is in close proximity to an intersection, an engineering study should be performed to determine if emergency vehicle preemption is appropriate.

Support:

"Official" vehicles are fire-fighting and emergency medical service vehicles owned, operated, and maintained by the emergency response agency or authority. Authorized law enforcement vehicles that utilize sirens and blue flashing lights are considered eligible vehicles.

Section 4F.02 Design of Emergency-Vehicle Traffic Control Signals

Standard:

Except as specified in this section, an emergency-vehicle traffic control signal shall meet the requirements of the *MUTCD* and the *NCSMUTCD*.

The following size lenses shall be used for emergency-vehicle traffic control signals if the signal is used exclusively for emergency-vehicle control: 12 inch (300 mm) diameter for steady CIRCULAR RED and steady CIRCULAR YELLOW indications and 8 inch (200 mm) diameter for flashing yellow indication. A GREEN indication shall not be permitted in an emergency-vehicle traffic control signal installed at a mid-block location.

Section 4F.03 Operation of Emergency-Vehicle Traffic Control Signals

Standard:

An emergency-vehicle traffic control signal installed at a mid-block location shall be manually actuated from a local control point or from an emergency vehicle equipped for remote operation of the signal.

As a minimum, the indications sequence, and manner of operation of an emergency-vehicle traffic control signal installed at a mid-block location shall be as follows:

A. Between emergency vehicle actuations, the signal indication on the major roadway shall be flashing yellow.

B. Upon emergency vehicle actuation, a steady yellow change interval shall be displayed to traffic on the major roadway.

C. A yellow change interval is not required following the green interval for the emergency-vehicle driveway.

D. During the emergency vehicle preemption phase, a steady red signal indication shall be displayed for traffic on the major roadway.

CHAPTER 4G. TRAFFIC CONTROL SIGNALS FOR ONE-LANE, TWO-WAY FACILTITES

Section 4G.02 Design of Traffic Control Signals for One-Lane, Two-Way Facilities

Standard:

The provisions of Chapter 4D of the *MUTCD* and *NCSMUTCD* shall apply to traffic control signals for one-lane, two-way facilities except that:

A. The duration of red clearance intervals shall be adequate to clear the one-lane section of conflicting vehicles.

B. A means, such as interconnection, shall be provided to prevent conflicting signal indications, e.g., green and green, at opposite ends of the section.

CHAPTER 4H. TRAFFIC CONTROL SIGNALS FOR FREEWAY ENTRANCE RAMPS

Section 4H.02 Design of Freeway Entrance Ramp Control Signals

Standard:

In addition to the standard design specifications set forth in Section 4H.02 of the *MUTCD*, all signal sections used in ramp control signals shall have 12 inch (300 mm) diameter lenses.

CHAPTER 4I. TRAFFIC CONTROL SIGNALS FOR MOVABLE BRIDGES

Section 4I.02 Design and Location of Movable Bridge Signals and Gates

Standard:

The design and location of signal heads and mountings for movable bridge signals shall follow the provisions of Chapter 4D of the *MUTCD* and *NCSMUTCD* except as noted below.

Since movable bridge operations cover a variable range of time periods between openings, the signals shall be the standard three color traffic signals consisting of a CIRCULAR RED, CIRCULAR YELLOW, and CIRCULAR GREEN lens in each signal face. Two signal indications shall be provided for each approach to the movable span.

Signal heads with 12 inch (300 mm) diameter lenses shall be used for each approach to movable bridge spans.

Section 4I.03 Operation of Movable Bridge Signals and Gates

Standard:

The CIRCULAR GREEN signal indication shall be illuminated at all times between bridge openings. The signal shall display a steady CIRCULAR RED indication when traffic is required to stop. A yellow change interval shall be provided between the display of the green and red indications.

Option:

If the bridge is not expected to open during continuous periods in excess of 5 hours, a flashing **CIRCULAR YELLOW** indication may be used.

CHAPTER 4J. LANE-USE CONTROL SIGNALS

Section 4J.03 Design of Lane-Use Control Signals

Standard:

The bottom of any lane-use control signal unit shall be at least 16.5 feet (5.0 meters) above the crown of the pavement.

CHAPTER 4K. FLASHING BEACONS

Section 4K.02 Intersection Control Beacon

Support:

Whereas a beacon is considered a form of a traffic signal, a minimum of two sections, in accordance with Section 4D.15 of the *MUTCD* and *NCSMUTCD*, are required for each approach at a beacon. The size of the beacon sections are either 8 inch (200 mm) or 12 inch (300 mm) based on the criteria of Section 4D.15 of the *MUTCD* and *NCSMUTCD*.

Standard:

There shall be a minimum of two sections with the appropriate lenses in each section used for every approach to an intersection under beacon control. The size of the beacon shall be established according to Section 4D.15 of the *MUTCD* and *NCSMUTCD*.

If the beacon is suspended over the roadway, the clearance between the crown of the pavement and lowest point of the beacon shall be at least 16.5 feet (5.0 meters).

Guidance:

For single-lane approaches, the beacon sections should be vertically aligned and alternately flashed unless an engineering study indicates otherwise. The vertical distance from the bottom of the top beacon to the top of the bottom beacon should be 18 inches (450 mm).

For multi-lane approaches, the beacon sections should be mounted horizontal to each other and flash simultaneously.

Section 4K.03 Warning Beacon

Support:

A warning beacon consists of a flashing **CIRCULAR YELLOW** signal lens or multiple lenses which are used in conjunction with a warning or regulatory sign to alert drivers to a potential hazard in or adjacent to the roadway ahead. The flashing beacons are intended to help draw attention to the sign or other device, which might otherwise be ignored by the driver.

Standard:

Where two lenses are aligned horizontally, they shall flash simultaneously. If two lenses are aligned vertically, they shall flash alternately.

If a warning beacon is suspended over the pavement, the clearance between the crown of pavement in the roadway and the lowest point of the beacon shall be at least 16.5 feet (5.0 meters) but not more than 19 feet (5.8 meters).

Guidance:

The edge of housing should normally be located no closer than 12 inches (300 mm) outside of the nearest edge of the sign.

Section 4K.06 Overheight Vehicle Detection Warning Beacons

Support:

Some overpasses on primary highways do not provide adequate clearance for vehicles passing beneath the structure. To warn overheight vehicles of potentially low clearance overpasses, detectors and warning beacons are installed to alert the driver of the potential hazard ahead. The actuated device is intended to attract the driver's attention better than a warning beacon, which is in permanent flashing operation.

Standard:

When the warning beacons are suspended over the pavement, the clearance between the crown of pavement in the roadway and the lowest point on the sign or signal head shall be at least 16.5 feet (5.0 meters).

Guidance:

An advance sign with the message "**VEHICLE OVERHEIGHT WHEN FLASHING**" (W14-17) should be mounted over the roadway between two single section 12 inch (300 mm) **CIRCULAR YELLOW** flashers. The beacons should be activated whenever a special detection device senses that the top of the vehicle is less than 12 inches (300 mm) from the bottom of the overpass.

Option:

Overheight vehicle detection beacons may be installed prior to underpasses where there has been a problem of overheight vehicles striking the overpass. The beacons may flash either simultaneously or alternately, in accordance with Section 4K.03.